PART I - ADMINISTRATIVE

Section 1. General administrative information

Title of project

Snake River Sockeye Salmon Habitat And Limnological Research

BPA project number: 9107100
Contract renewal date (mm/yyyy): 8/1999 ☒ **Multiple actions?**

Business name of agency, institution or organization requesting funding
Shoshone-Bannock Tribes

Business acronym (if appropriate) SBT

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NPPC Program Measure Number(s) which this project addresses
2.2A, 7.5A, 7.6A

FWS/NMFS Biological Opinion Number(s) which this project addresses

Other planning document references
Proposed Recovery Plan for Snake River Salmon 1.3.a and 1.6.c, CBFWA FY99 DAIWP - Salmon River Subbasin

Short description
Increase carrying capacities of Snake River sockeye salmon rearing lakes (Redfish, Pettit, and Alturas). Evaluate the effects of nutrient additions and fish stocking on the lake's ecosystems.

Target species
Snake River sockeye salmon

Section 2. Sorting and evaluation

Subbasin
Salmon River

Evaluation Process Sort

CBFWA caucus	Special evaluation process	ISRP project type
Mark one or more	If your project fits either of these	Mark one or more categories

caucus	processes, mark one or both	
☒ Anadromous fish ☐ Resident fish ☐ Wildlife	☒ Multi-year (milestone-based evaluation) ☐ Watershed project evaluation	☐ Watershed councils/model watersheds ☐ Information dissemination ☐ Operation & maintenance ☐ New construction ☐ Research & monitoring ☒ Implementation & management ☐ Wildlife habitat acquisitions

Section 3. Relationships to other Bonneville projects

Umbrella / sub-proposal relationships. List umbrella project first.

Project #	Project title/description

Other dependent or critically-related projects

Project #	Project title/description	Nature of relationship
9107200	Redfish Lake sockeye captive broodstock	
9204000	Redfish Lake sockeye salmon captive broodstock rearing	
9009300	Genetic analysis of Oncorhynchus nerka	

Section 4. Objectives, tasks and schedules

Past accomplishments

Year	Accomplishment	Met biological objectives?
1994	Fertilization experiment in limnocorral enclosures in Redfish Lake.	Yes, treatment enclosures showed an increase in both chlorophyll a and zooplankton compared to the control enclosures.
1995	Test fertilization of Redfish Lake.	Yes, zooplankton biomass increased over previous years despite the addition of 83,000 sockeye pre smolts.
1995	Reduce the number of non-endemic spawning kokanee in Fishhook Creek.	No, our weir was inneffective at capturing adult kokanee.
1997	Fertilize lakes to increase sockeye carrying capacity and overwinter survival of released sockeye pre smolts in Redfish, Alturas, and Pettit lakes.	Yes, chlorophyll a increased, zooplankton biomass remained high, and the overwinter survival rate was the highest since the inception of the program despite the addition of 153,000 sockeye pre smolts in Redfish Lake.

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Continue extensive limnological monitoring in Redfish, Alturas, and Pettit lakes. Continue monitoring limnological parameters in Stanley Lake with a less intensive schedule.	a	Conduct ongoing limnological studies during 1999 and 2000 to provide information on physical, chemical, and biological characteristics relating to O. nerka production. This includes a lake fertilization monitoring program.
		b	Complete winter limnology sampling and estimate sockeye salmon production opportunities and constraints during this season.
		c	Coordinate efforts with the USFS, IDFG, Idaho State Dept. of Water Resources.
2	Fertilize Redfish, Alturas, and Pettit lakes.	a	Apply pharmaceutical grade nitrogen and phosphorous by boat at weekly intervals. Rates of application had already been determined for 1998 and after evaluating 1998 limnological data and O. nerka population estimates those rates may change for 1999.
		b	Obtain a lake fertilization prescription from Dr. John Stockner based on 1998 limnological data.
3	Enumerate sockeye smolt outmigration from Pettit and Alturas lakes. We will use a smolt collection weir and a screw trap at the outlet streams of Pettit and Alturas lakes, respectively.	a	Collect sockeye smolts from Alturas and Pettit lakes. Enumeration and potential PIT tagging (pending TOC recommendation) will be undertaken at each location.
4	Continue monitoring O. nerka population characteristics and densities in the Sawtooth Valley lakes in conjunction with IDFG to determine inter-annual trends.	a	Estimate the emergent O. nerka fry population entering Redfish Lake. Estimate summer survival of age-0 fish by comparing population estimate to end of the summer trawl/hydroacoustic work.
		b	Estimate O. nerka stream spawner population size and sex ratio in Redfish (Fishhook Crk.), Alturas, and Stanley lakes using spawning ground surveys. Estimate spawner distribution, stream residency, and fecundity of spawning kokanee for each stream.
		c	Estimate the total number of O. nerka in Sawtooth Valley lakes (Redfish, Alturas, Pettit, and Stanley) using hydroacoustics. Use vertical gillnets to partition targets. Determine year class strength and mortality.
		d	Correlate hydroacoustic population estimates with IDFG's trawling estimates.
5	Determine seasonal loss of O. nerka to piscivorous fish in the Sawtooth Valley lakes.	a	Estimate potential predation and competition impacts to O. nerka by nursery lake fish community constituents by stomach content analysis of gill-net captured fish in Alturas & Pettit lakes. Samples will come from different time

			periods and lake locations.
6	Assist the IDFG with in-lake captive broodstock production activities for progeny from the captive rearing programs.	a	Assist IDFG with developing O. nerka juvenile release strategy protocols and evaluation of fish performance.
		b	Assist IDFG with construction and maintenance of net pens used to rear O. nerka juveniles in the Sawtooth Valley nursery lakes.
		c	Assist IDFG with placement and retrieval of egg incubation boxes in Redfish Lake.
		d	Assist IDFG personnel, where needed, with PIT tagging of sockeye salmon destined for nursery lake re-introduction.
		e	Solicit and obtain written recommendations from other sockeye salmon experts on release and lake production strategies.
7	Technology Transfer	a	Provide written reports to the Stanley Basin Technical Oversight Committee.
		b	Provide an annual report to the BPA.
		c	Attend appropriate conferences and meetings that relate to sockeye salmon. Give presentations on project to professional organizations, conferences, etc.

Objective schedules and costs

Obj #	Start date mm/yyyy	End date mm/yyyy	Measureable biological objective(s)	Milestone	FY2000 Cost %
1	9/1991	10/2010			25.00%
2	6/1995	10/2010			27.00%
3	4/1996	8/2015			16.00%
4	9/1991	8/2015			11.00%
5	9/1991	10/2010			7.00%
6	9/1991	10/2010			3.00%
7	9/1991	12/2015			11.00%
				Total	100.00%

Schedule constraints
End dates for most objectives are impossible to predict. Many tasks are dependant on the number of returning adults, lake habitat conditions, number of progeny available from the captive broodstock program, etc.

Completion date
2015

Section 5. Budget

FY99 project budget (BPA obligated): $417,000

FY2000 budget by line item

Item	Note	% of total	FY2000
Personnel	three 12 mo. FTE, one 9 mo. FTE, one 6 mo. FTE, one 1 mo. FTE	%28	122,361
Fringe benefits		%9	41,603
Supplies, materials, non-expendable property		%1	5,500
Operations & maintenance		%16	71,490
Capital acquisitions or improvements (e.g. land, buildings, major equip.)		%0	0
NEPA costs		%0	0
Construction-related support		%0	0
PIT tags	# of tags: 500	%0	1,450
Travel	includes per diem, etc. for field work	%8	33,000
Indirect costs		%11	46,615
Subcontractor	Biolines and Eco-Logic Ltd.	%22	97,442
Subcontractor	Washington State University	%4	19,000
Other		%0	0
TOTAL BPA FY2000 BUDGET REQUEST			$438,461

Cost sharing

Organization	Item or service provided	% total project cost (incl. BPA)	Amount ($)
		%0	
		%0	
		%0	
		%0	
Total project cost (including BPA portion)			$438,461

Outyear costs

	FY2001	FY02	FY03	FY04
Total budget	$451,000	$460,000	$467,000	$467,000

Section 6. References

Watershed?	Reference
☐	Bevan, D., J. Harville, P. Bergman, J. Crutchfield, P. Klingeman, and J. Litchfield. 1994. Snake River Salmon Recovery Team: Final recommendations to National Fisheries Service.
☐	Bowles, E.C., and T. Cochnauer. 1984. Potential sockeye salmon production in Alturas Lake Creek drainage, Idaho. Prepared for USDA, Forest Service Sawtooth National Forest.
☐	Bjornn, T.C., D.R. Craddock, and D.R. Corley. 1968. Migration and survival of Redfish Lake, Idaho, sockeye salmon, Oncorhynchus nerka. Trans. Am. Fish. Soc. 97(4): 360-373.
☐	Budy, P., C. Luecke, W.A. Wurtsbaugh, and H. P. Gross. 1994. Effects of nutrient enhancement on plankton and the growth of juvenile salmon in Redfish Lake. IN D. Tuescher and D. Taki, eds. Snake River sockeye habitat and limnological research - annu
☐	Budy, P., C. Lueke, and W.A. Wurtsbaugh. 1996. A comparison of four years of limnology

	in the Sawtooth Lakes with emphasis on fertilization of Redfish Lake. IN, D. Tuescher and D. Taki, eds. Snake River sockeye salmon habitat and limnological research
☐	Budy, P., C. Lueke, W.A. Wurtsbaugh, H.P. Gross, and C. Gubala. 1995. Limnology of the Sawtooth Valley Lakes with respect to potential growth of juvenile sockeye salmon. Northwest Sci. 69: 33-150.
☐	Budy, P., C. Luecke, and W.A. Wurtsbaugh. 1998. Adding nutrients to enhance the growth of endangered sockeye salmon: trophic transfer in an oligotrophic lake. Trans. Am. Fish. Soc. 127: 19-34.
☐	Edmundson, J., and L. Peltz. 1990. Juvenile sockeye salmon outplants into Pass and Esther Passage lakes, and the nutrient enrichment of Pass Lake. Proceedings of the 1990 sockeye culture workshop. Anchorage, Alaska. Alaska Department of Fish and Game
☐	Gross, H.P., W.A. Wurtsbaugh, C. Luecke, and P. Budy. 1994. Comparison of epilimnetic and metalimnetic fertilizations on the phytoplankton and zooplankton in Pettit Lake, Idaho. IN D. Tuescher and D. Taki, eds. Snake River sockeye habitat and limn
☐	Gross, H.P. 1995. Evaluation of lake fertilization as a tool to assist in the recovery of the Snake River sockeye salmon. M.S. thesis, Utah State University, Logan, Utah.
☐	Gross, H.P., W.A. Wurtsbaugh, C. Luecke, and P. Budy. 1997. Fertilization of an oligotrophic lake with a deep chlorophyll maximum: predicting the effect on primary productivity. Can. J. Fish. Aquat. Sci. 54: 1177-1189.
☐	Hyatt, K.D., and J.G. Stockner. 1985. Responses of sockeye salmon to fertilization of British Columbia coastal lakes. Can. J. Fish. Aquat. Sci. 42: 320-331.
☐	Koenings, J.P., and R.D. Burkett. 1987. Population characteristics of sockeye salmon smolts relative to temperature regimes, euphotic volume, fry density, and forage base within Alaskan lakes. p. 216-234. IN H.D. Smith, L. Margolis, and C.C. Wood, ed
☐	Kyle, G.B. 1994. Assessment of trophic level responses and coho salmon (Oncorhynchus kisutch) production following nutrient treatment (1981-1986) of Bear Lake, Alaska. Fisheries Research 20: 294-261.
☐	Luecke, C., P. Budy, W.A. Wurtsbaugh, H.P. Gross, and G. Steinhart. 1996. Simulated growth and production of endangered Snake River sockeye salmon: assessing lake management strategies for nursery lakes. Fisheries (Bethesda), 21(6): 18-25.
☐	National Marine Fisheries Service. 1994. Biological Opinion. Trapping of Alturas Lake kokanee Oncorhynchus nerka outmigrants during the spring of 1994-1997. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ma
☐	National Marine Fisheries Service. 1995. Proposed Recovery Plan for Snake River Salmon. U. S. Department of Commerce, National Oceanic and Atmospheric Administration.
☐	National Marine Fisheries Service. 1996. Section 10 permit to take endangered species. Permit number 998. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Springs, Maryland.
☐	Plante, C., and J.A. Downing. 1992. Relationship of salmonine production to lake trophic status and temperature. Can. J. Fish. Auqat. Sci. 50: 1324-1328.
☐	Rieman, B.E., and D.L. Meyers. 1992. Influence of fish densities and relative productivity of growth of kokanee in ten oligotrophic lakes and reservoirs in Idaho. Trans. Am. Fish. Soc. 121: 178-191.
☐	Robinson, D.G., and W.E. Barraclough. 1978. Population estimates of sockeye salmon in a fertilized oligotrophic lake. J. Fish. Res. Board Can. 35: 851-860.
☐	Stockner, J.G. 1996. An assessment of rearing capacity of Stanley Basin lakes for sockeye salmon, Oncorhynhus nerka; recommendations for enhancement by whole lake fertilization; and comments on limnological monitoring. Prepared for Doug Taki, Shoshone-
☐	Stockner, J.G., K. Shortreed, J. Hume, K. Morton, and M. Henderson. 1995. PR Model; unpublished data obtained through personal communication.
☐	Stockner, J.G., and E.A. MacIsaac. 1996. British Columbia lake enrichment programme: two decades of habitat enhancement for sockeye salmon. Regulated Rivers: Research and Management 12: 547-561.
☐	Taki, D. and A. Mikkelsen. 1997. Fish population dynamics in Sawtooth Valley lakes. IN, D. Taki and A. Mikkelsen, eds. Snake River sockeye salmon habitat and limnological

	research-1996 annual report. U.S. Dept. of Energy, Bonneville Power Administrat
☐	Tuescher, D., and D. Taki. 1995. Lake carrying capacity and production estimates. IN, D. Tuescher and D. Taki, eds. Snake River sockeye salmon habitat and limnological research-1994 annual report. U.S. Dept. of Energy, Bonneville Power Administration
☐	Tuescher, D. and D. Taki. 1996. Fish population dynamics in Sawtooth Valley Lakes. IN, D. Tuescher and D. Taki, eds. Snake River sockeye salmon habitat and limnological research-1994 annual report. U.S. Dept. of Energy, Bonneville Power Administratio
☐	Zadina, T., and M. Haddix. 1993. Consequences and solution to early fry release timing in Virginia Lake. Proceedings of the 1990 sockeye culture workshop. Anchorage, Alaska. Alaska Department of Fish and Game.

PART II - NARRATIVE

Section 7. Abstract

This project assesses habitat limitations for Snake River sockeye salmon *O. nerka*, and investigates fish community dynamics in sockeye nursery lakes, including the relationships between resident and anadromous forms of *O. nerka* in current or potential Sawtooth Valley production areas. We will continue activities (especially lake fertilization) necessary to increase or re-establish sockeye production in historic nursery lakes of the Sawtooth Valley, Idaho as recommended by the Stanley Basin Sockeye Technical Oversight Committee. We will continue to assist the Idaho Department of Fish and Game (IDFG) in captive broodstock activities such as net pen deployment and assessment of sockeye salmon performance in nursery lakes through smolt emigration. Our immediate objective is to increase survival of captive broodstock progeny from the time they are stocked in the lake until they emigrate.

Limnological conditions and fish interactions (competition/predation) are used to estimate sockeye carrying capacities for each lake. Without this data, stocking at densities greater than existing carrying capacities could result in a zooplankton crash which would reduce available rearing habitats and impede recovery.

Our limnology and lake fertilization efforts directly address 7.5A.l and 7.6A.2 in the Fish and Wildlife Program (NPPC 1994). We also removed a passage barrier on the outlet of Pettit Lake Creek that is called for in both 7.5A.1 and 7.6A.2. This project also addresses objectives for the Salmon sub-basin found in the FY99 DAIWP, specifically 3) improve juvenile rearing and over-wintering survival; and 4) improve summer parr survival.

Methodologies for limnological monitoring and lake fertilization are standard methods that have been used for decades in Alaskan and Canadian sockeye rearing lakes. Dr. John Stockner, a Canadian researcher with more than two decades of sockeye research experience, provided a lake fertilization prescriptions. Quantities of fertilizer and application rates were formulated for each lake that should increase forage resources for juvenile sockeye without detrimental effects on the lakes' ecosystems.

We expect to increase the number of returning adult sockeye to the Sawtooth Valley, Idaho. Evaluation of any particular management activity requires two to four years, based on a typical Snake River sockeye life cycle.

Section 8. Project description

a. Technical and/or scientific background

Although the Northwest Power Planning Act of 1980 was congressionally enacted to restore depleted salmon runs, the remnant Snake River sockeye salmon run to Redfish

Lake near Stanley, Idaho has continued to decline toward extinction throughout the 1980's and 1990's (National Marine Fisheries Service 1995). From 1954 to 1966 the largest number of adult sockeye salmon escaping to Redfish Lake was 4,361 fish in 1955 (Bjornn et al. 1968). No sockeye returned to Redfish Lake in 1990, 1995, and 1997. Escapement to the Redfish Lake weir during the 1990's was highest in 1993 when eight fish returned. Snake River sockeye were officially listed as an endangered species in 1991 (56 FR 58619), necessitating the implementation of a multi-agency recovery program.

This project has been adaptively managed by the Stanley Basin Technical Oversight Committee (TOC) since its inception. The TOC is an inter-agency team of scientists with the expertise needed to recommend actions necessary to increase production of Snake River sockeye. Current members of the TOC are the SBT, the National Marine Fisheries Service (NMFS), the University of Idaho (UI), the Idaho Department of Fish and Game (IDFG), the BPA, the Idaho Department of Environmental Quality (DEQ), and the U.S. Forest Service (USFS). All activities addressed in this project have been endorsed by the TOC.

We hypothesized that the decline in numbers of returning sockeye and the subsequent loss of those marine derived nutrients has resulted in decreased productivity of the Sawtooth Valley lakes. This could not be verified because there is no historic limnological data available for the Sawtooth Valley lakes. To determine lake productivity's, in 1992 we began intensive limnological and fish community assessments of Redfish, Pettit, Alturas, and Stanley lakes. Limnological parameters we sample include: water temperature, dissolved oxygen, and conductivity profiles, water transparency, light penetration, nutrient concentrations (TP, NO2+NO3-N, NH4-N, and TKN), primary productivity, chlorophyll *a* concentrations, and phytoplankton and zooplankton taxonomic composition, density, and biomass. In 1992 and 1993, sampling was conducted monthly during ice-free months and in 1994 winter sampling was initiated. Currently, sampling is conducted once or twice per month during every month except February, April, and December. We use this data to estimate *O. nerka* carrying capacities for each lake. Fish communities are sampled in each lake to determine species composition and diet. Densities of individual cohorts and total lake populations of kokanees are also monitored annually.

The combination of high densities of non-endemic kokanees and the oligotrophic conditions of the rearing lakes result in little habitat being available for introduced sockeye from the captive broodstock program (Budy et al. 1995; Teuscher and Taki 1995). Lake nutrient enhancement has been successful in increasing lake production in other sockeye rearing lakes in Alaska and Canada (Robinson and Barraclough 1978; Hyatt and Stockner 1985; Kyle 1994; Stockner and MacIsaac 1996). In 1993, we began evaluating nutrient additions as a tool to increase survival of stocked sockeye pre-smolts in the Sawtooth Valley lakes (Budy et al. 1994; Gross et al. 1994; Gross 1995; Luecke et al. 1996; Gross et al. 1997; Budy et al. 1998).

Experiments were performed in large (350 m^3) limnocorral enclosures, which were slowly dropped into the lakes with the bottom open and allowed to fill with lake water then closed by SCUBA divers. In 1994, the experimental design included a control (C), and two treatments (F), and (NF), each with three replicates (Budy et al. 1998). Treatment F was stocked with juvenile kokanees and treatment NF received nitrogen, phosphorous and juvenile kokanees. Nutrients were added for two months prior to the addition of fish in treatment NF. The experiment was conducted in two parts, part 1 (13 June-12 August) where nutrients were added to three limnocorrals (NF), and part 2 (13 August – 11 September) where nutrient additions were continued and fish were added to the three NF and three F treatments. During the 1993 experiment, fish were added concurrently with nutrients, chlorophyll *a* increased but there was no significant increase in zooplankton biomass (Budy et al 1994). This information was used to alter the 1994 study design to allow nutrient addition effects on lower trophic levels to take place before the introduction of fish. The 1994 experiment was statistically analyzed as the two parts described above using repeated measure ANOVA's, accounting for time and differences among treatments. In part one there were two treatments with three replicates for the NF and six replicates for the control treatments (C and F). In part two there were three replicates of each of the three treatments C, F, and NF.

The enclosures were sampled every ten days for water transparency, temperature, oxygen, and zooplankton abundance and biomass. Water was collected four times during the experiment to sample TP, SRP, TKN, and NO_3. Primary production was measured twice. Juvenile kokanee were measured and weighed before introduction and at the end of the experiment. See Budy et al. (1998) for a more detailed description of methods used for these experiments.

The results from the 1994 experiment indicated that nutrient enhancement would increase lake productivity. Chlorophyll *a* increased significantly in the both the epilimnion and metalimnion in the NF treatment prior to addition of fish (Budy et al. 1998). Integrated samples taken from the whole water column showed a significant increase during both parts of the experiment. Total zooplankton biomass followed a similar increase as chlorophyll *a* in part one, yet continued to be greater than the C and F treatments after the addition of fish in the NF treatment. Growth of fish in the NF treatment was higher than in the F treatment although this difference was not significant ($P = 0.36$) (Budy et al. 1995; Budy et al. 1998).

In 1994 we did a literature search and found five different models to predict carrying capacities for *O. nerka* (Teuscher and Taki 1995). Four models relate fish production to lower trophic level productivity: 1) chlorophyll *a* model (Rieman and Meyers 1992), 2) euphotic volume (Koenings and Burkett 1987), 3) total phosphorous (Plante and Downing 1992), and 4) primary production (PR)(Stockner et al. 1995). A fifth model, stock recruitment (Bowles and Cochnauer 1984) used sockeye survival at various life stages as well as predation by other fish and potential harvest.

Based on the limnological data collected, we felt that the PR model was best suited for the conditions of the lakes in the Sawtooth Valley. Using this model, we predicted a carrying capacity of 2,600 kg of *O. nerka* biomass for Redfish Lake (Teuscher and Taki 1995). Hydroacoustic surveys indicated that there was already 2,400 kg of kokanee biomass present in the lake which only left room to stock 20,000 10g smolt equivalents. Edmundson and Peltz (1990) and Zadina and Haddix (1993) reported declines in sockeye growth and survival after supplementation exceeded carrying capacities. Since we were planning to stock over 80,000 sockeye from the captive broodstock program, the TOC recommended a test fertilization of Redfish Lake in 1995.

During lake fertilization in 1995, epilimnetic chlorophyll *a* remained similar to the three previous years in Redfish Lake and water transparencies were only slightly shallower (Budy et al. 1996.). Even though chlorophyll *a* showed little increase in 1995, primary productivity was approximately 100% higher than the other lakes. Phytoplankton biovolume during the July and August sampling was highest in 1995 although the annual mean was below that observed in1993. All the lakes were at their highest phytoplankton biovolume in 1993, the first normal water year following six years of drought. Zooplankton biomass followed the same seasonal pattern as previous years with the peak in summer and fall and low densities in the winter and spring. However, in early October of 1995 biomass exceeded 20 Φg/l. The previous high in Redfish Lake was less than
12 Φg/l. In addition to total biomass, *Daphnia* biomass was higher than the previous three years.

Concurrent to lake fertilization we attempted to limit the kokanee biomass in Redfish Lake. Two different options were presented: 1) reduce the number of fry recruiting to Redfish Lake from Fishhook Creek, and 2) reduce the number of adult kokanee spawners in Fishhook Creek. During 1995 we employed both methods (Teuscher and Taki 1996). A portion of the fry were collected in early 1995 and transported to the Sawtooth Hatchery to be stocked at a different lake in the valley as was requested at a meeting with the Custer County Commissioners. That summer we attempted to capture adult spawners as they entered the stream with a goal of releasing 2,000 females to spawn. Egg deposition from 2,000 females would have been approximately 460,000 eggs with a resulting fry recruitment to Redfish Lake of approximately 60,000 fry. Unfortunately, the weir did not operate well and our goal was not achieved.

Again in 1997, abundant numbers of progeny from the captive broodstock program were available to supplement the Sawtooth Valley lakes. With over 250,000 fish available we were able to put sockeye pre-smolts into all three lakes where access was available (Taki et al. in review). The PR model predicted that unfertilized carrying capacities for Redfish, Pettit, and Alturas lakes would be 5.5 kg/ha, 7.04 kg/ha, and

6.03 kg/ha, respectively. With lake fertilization the carrying capacities increased to 9.96, 11.04, and 10.53 kg/ha for Redfish, Pettit, and Alturas lakes, respectively (Stockner 1996).

During January of 1997 we estimated that in October total *O. nerka* biomass would be 6.24 (IDFG) to 7.69 kg/ha (SBT) in Redfish Lake (TOC January 1997). This included background biomass of kokanees and supplemented sockeye. We estimated *O. nerka* biomass in Pettit Lake would be 16.2 kg/ha and 2.5 kg/ha for Alturas Lake. Based on this information the TOC endorsed the idea of fertilizing all three lakes. Because Pettit Lake was estimated to exceed carrying capacity only 8,600 sockeye were stocked there. This decision was based on the high overwinter survival of sockeye stocked there in 1995 under similar lake productivity conditions (Taki and Mikkelsen 1997). Although Alturas Lake was projected to remain below its unfertilized carrying capacity, we recommended lake fertilization to speed zooplankton recovery after a crash in the early 1990's.

In addition to lake fertilization, 1997 was a near record high water year. Chlorophyll *a* levels in Redfish and Pettit lakes were about double and Alturas Lake was 150% of the six-year mean. Stanley Lake, a lake with kokanees that was not fertilized was 140% of the six-year mean (TOC March 1998). Primary production also was well above average for all the lakes. It appears that high run off increased production in all lakes while Redfish and Pettit lakes possibly showed the effects of lake fertilization. Despite the addition of sockeye broodstock progeny to the lakes, zooplankton biomass remained high. The mean annual value of 8.2 Φg/l of zooplankton biomass in Redfish Lake was higher than in 1996, 11.2 Φg/l of biomass in Pettit Lake was the highest in the last three years, and 11.0 Φg/l in Alturas Lake was the highest we have recorded.

Sockeye smolt outmigration from Alturas Lake was approximately 32,500, a 34.3% survival rate from time of release in 1997 to outmigration in 1998. This was the highest survival rate we have seen from any release of captive broodstock progeny. Smolt outmigration from Redfish Lake indicated an approximate overwinter survival of 20%, matching the highest survival rate recorded even though over 150,000 sockeye pre-smolts were stocked into that lake.

b. Rationale and significance to Regional Programs

Section 7 of the FWP (1994) calls for a coordination of salmon production and habitat. This project evaluates and enhances habitat for Snake River sockeye and is intimately involved with sockeye production from the captive broodstock programs (Project numbers 9107200 and 9204000). Lake fertilization and barrier removal are identified as tasks 1.3.a and 1.6.c in the Proposed Recovery Plan for Snake River Salmon (NMFS 1995) and 7.5A.1 in the FWP (1994). The Snake River Salmon Recovery Team (Bevan et al. 1994) also recommended implementing those measures in chapter 5, section 6. As noted above in 8a., all Snake River sockeye recovery efforts are coordinated through the TOC and each individual project is dependent upon the other.

The overall objective of this project is to increase sockeye populations in the Sawtooth Valley, Idaho that directly addresses Section 2.2A of the FWP (1994) that states "The program preference is to support and rebuild native species in native habitats, where feasible." In order to increase sockeye populations we need to increase survival during their freshwater life stage. The null hypothesis, H_o = adding nutrients to sockeye rearing lakes will not affect sockeye survival, was rejected during our first year of lake fertilization. Captive broodstock progeny released in Redfish Lake during 1994, when there was no lake fertilization, had an estimated survival from time of release to outmigration of 5.4%. Sockeye released during 1995, the first year of fertilization, had an estimated survival from time of release until outmigration of 15.8%. Based on those results, we began fertilizing Alturas and Pettit lakes in 1997 to try to increase survival of sockeye released into those lakes. Results of smolt outmigration from Pettit Lake in 1998 have not been finalized. As noted above, Alturas Lake had the highest survival rate we have documented from the Sawtooth Valley lakes. One must use caution when comparing survival rates because of the many confounding factors involved. Annual variations in predator abundance, competition from kokanees, climatic conditions, and snowpack, all confound a simple fertilized versus non-fertilized analysis.

c. Relationships to other projects

This project is one component of an inter-agency effort to restore Snake River sockeye salmon runs to the Sawtooth Valley, Idaho. As mentioned in Section 8a, all activities involved in our recovery efforts are coordinated through the TOC. Shoshone-Bannock Tribes' fisheries personnel involved with this project work closely with their counterparts in the IDFG (Project Number 9107200) and the NMFS (Project Number 9204000). Cooperation is evident by the coordination of field activities and the sharing of personnel between agencies.

Overall project goals are similar for all of the agencies involved - the immediate goal is to prevent extinction of the ESU, and the overall goal of having a viable population of Snake River sockeye salmon is shared by all. The scope of this program dictates that each project is responsible for specific tasks involved to reach our mutual goal. Achievements by each agency have contributed to making informed decisions regarding management issues and future direction of our work.

Genetic analyses of the *O. nerka* populations in the Sawtooth Valley lakes by the NMFS and the University of Idaho have defined which stocks may be endemic and which are introduced. That information has allowed us to focus our efforts toward sustaining the ESU without expending energies on non-endemic stocks. Improvements in culture techniques by the IDFG and the NMFS have made progeny from the sockeye broodstock program available in large enough numbers that we have been able to reintroduce sockeye to Pettit and Alturas lakes. Our work has enabled the TOC to decide upon release strategies for those fish, and has improved rearing habitat as they become available for release into the lakes. We have also increased available habitat by removing the fish passage barrier below Pettit Lake. This was done in collaboration with the Forest Service, the DEQ, the BPA, and the IDFG.

d. **Project history** (for ongoing projects)

This project began in 1991 after Snake River sockeye salmon were listed as an endangered species. The seven-year average expenditure for this project is $483,223. Since 1991, we have successfully fertilized Redfish Lake for three ½ years and Pettit and Alturas lakes for two years. We removed the fish passage barrier from Pettit Lake Creek and installed a weir near that location. The barrier removal was the single greatest expenditure during this project.

Based on our annual evaluations of lake rearing conditions the TOC is able to recommend stocking rates for each lake. As previously mentioned, annual variations in predator abundance, competition from kokanees, climatic conditions, and snowpack all effect lake production. The lake fertilization program has to adhere to DEQ water quality criteria. Because of our permit with DEQ, this project is adaptively managed by the TOC on a "real time" basis. Depending on the monitoring parameter, weekly and/or biweekly sampling and data analysis is required. If DEQ water quality criteria are exceeded at any time during our fertilization season, we are required to discontinue fertilization efforts until parameter levels return to criteria guidelines. In fact, these criteria are sometimes exceeded during natural events. This example illustrates the adaptive nature of the program and the difficulty we have adhering to a regimented study design.

We have also evaluated the interactions of stocked hatchery rainbow trout with resident kokanees and stocked sockeye. Based on results of that study our recommendation to move to a pelagic release of pre-smolt sockeye was endorsed by the TOC.

Budy, P., C. Lueke, W.A. Wurtsbaugh, H.P. Gross, and C. Gubala. 1995. Limnology of the Sawtooth Valley Lakes with respect to potential growth of juvenile sockeye salmon. Northwest Sci. 69: 33-150.

Budy, P., C. Luecke, and W.A. Wurtsbaugh. 1998. Adding nutrients to enhance the growth of endangered sockeye salmon: trophic transfer in an oligotrophic lake. Trans. Am. Fish. Soc. 127: 19-34.

Gross, H.P. 1995. Evaluation of lake fertilization as a tool to assist in the recovery of the Snake River sockeye salmon. M.S. thesis, Utah State University, Logan, Utah.

Gross, H.P., W.A. Wurtsbaugh, C. Luecke, and P. Budy. 1997. Fertilization of an oligotrophic lake with a deep chlorophyll maximum: predicting the effect on primary productivity. Can. J. Fish. Aquat. Sci. 54: 1177-1189.

Luecke, C., P. Budy, W.A. Wurtsbaugh, H.P. Gross, and G. Steinhart. 1996. Simulated growth and production of endangered Snake River sockeye salmon: assessing lake management strategies for nursery lakes. Fisheries (Bethesda), 21(6): 18-25.

Spaulding, S. 1993. Snake river sockeye salmon (*Oncorhynchus nerka*) habitat/limnologic research. U.S.Department of Energy, Bonneville Power Administration, Portland, OR. Project number 91-71.

Taki, D., and A. Mikkelsen. 1997. Snake River sockeye salmon habitat and limnological research. U.S.Department of Energy, Bonneville Power Administration, Portland, OR. Project number 91-71.

Teuscher, D., and D. Taki. 1994. Snake River sockeye salmon habitat and limnological research. U.S.Department of Energy, Bonneville Power Administration, Portland, OR. Project number 91-71.

Teuscher, D., and D. Taki. 1995. Snake River sockeye salmon habitat and limnological research. U.S.Department of Energy, Bonneville Power Administration, Portland, OR. Project number 91-71.

Teuscher, D., and D. Taki. 1996. Snake River sockeye salmon habitat and limnological research. U.S.Department of Energy, Bonneville Power Administration, Portland, OR. Project number 91-71.

Wurtsbaugh, W.A., H.P. Gross, C. Luecke, and P. Budy. 1997. Nutrient limitation of oligotrophic sockeye salmon lakes of Idaho. Verh. Internat. Verein. Limnol. 26: 413-419.

e. Proposal objectives

1. Characterize limnologic attributes for Sawtooth Valley lakes to assess *O. nerka* production limitations and potential. Continue monitoring to characterize inter and intra-annual habitat fluctuations and improve carrying capacity estimates. Comply with DEQ monitoring requirements as specified in the nutrient enhancement consent order. Consult with independent experts to assure appropriate fertilization rates are used.

2. Implement and evaluate lake nutrient enhancement of Redfish, Pettit, and Alturas lakes during 1999. This objective will follow protocols of a successful test fertilization of Redfish Lake in 1995, with refinements made in successive years. We are trying to achieve a goal of 25% overwinter survival of sockeye released as pre-smolts.

3. Operate a smolt weir on the outlet of Pettit Lake and a screw trap on the outlet stream of Alturas Lake. This will enable us to estimate overwinter survival and outmigration rates of the broodstock sockeye released into those lakes during 1997.

4. Investigate *O. nerka* population dynamics in Stanley Basin lakes. Estimate species composition of potential fish predators (bull char, lake trout, rainbow trout, squawfish) and potential fish competitors (rainbow trout, brook char, and redside shiners) in Sawtooth Valley nursery lakes. Cooperate with IDFG researchers to obtain permitting under the Endangered Species Act to sample fish in Redfish Lake.

5. Determine predator effects on *O. nerka* population dynamics in relation to different release strategies. Continue sampling fish in Pettit Lake per the NMFS request to continue evaluation of hatchery rainbow trout/*O. nerka* interactions.

6. Assist IDFG with net pen construction and operation for rearing progeny of captive broodstock sockeye and monitoring subsequent survival and smolt production. Also, assist, as necessary, IDFG research biologist with field investigations related to sockeye salmon recovery.

f. Methods

Detailed methods for limnological monitoring can be found in Taki and Mikkelsen (1997). Following is our proposed sampling protocol for the Sawtooth Valley lakes.

Sample Redfish, Pettit and Alturas lakes twice per month from June through September and once per month in October, November, January, March and May. Sample Stanley Lake once per month in March, June, August and October. There are three sampling locations for each lake. A main station where all samples are taken for every parameter and two additional stations where zooplankton samples are also taken.

Collect temperature (^{o}C), dissolved oxygen (DO, mg/l) and conductivity (uS/cm) data each sample period at the main station of each lake using a Hydrolab® Surveyor3™ equipped with a Hydrolab H20® submersible data transmitter or a Yellow Springs Instrument Model 58 dissolved oxygen meter. Record temperature, dissolved oxygen and conductivity at one meter intervals from the surface to 10 m, one to two meter intervals from 10 m to the thermocline, then at 2-10 m intervals to the bottom.

Measure water transparency at the main station of each lake with a 20 cm secchi disk. Record depth at which secchi disappears, drop secchi and retrieve slowly, record depth secchi re-appears, and record transparency as the mean of the two values.

Identify the euphotic zone as defined by the one percent light level at the main station of each lake with a LiCorr® Li-1000 data logger equipped with a Li-190SA quantum sensor deck cell and a LI-193SA spherical sea cell. Measure photosynthetically active radiation (400-700 nm) at two meter intervals from surface to 2-4 m below the one percent light level. Simultaneously record deck and sea cell readings to correct for changes in ambient light. Depth of the one percent light level will be determined by linear regression of the natural log of percent surface light at each depth versus depth.

Collect water for nutrient analysis, chlorophyll *a* and phytoplankton at the main station of each lake from the epilimnion, metalimnion and hypolimnion during stratification. Collect three discrete water samples from each strata with a three L Van Dorn bottle and mix in a nine L churn splitter. When lakes are weakly stratified or isothermic, collect surface water from 0-6 m with a 25 mm diameter, 6m long lexan® tube. Collect discrete samples from mid-depth (Redfish = 45m, Pettit and Alturas = 25m, and Stanley = 12m) and 1-2 meters above the bottom.

Once per month or two times per month during lake fertilization analyze water for total phosphorous (TP) and nitrate (NO^2+NO^3-N). During June, August and October add assays for ammonium (NH^4) and kjeldahl nitrogen (TKN). Water for ammonium and nitrate-nitrite nitrogen assay will be filtered through 0.45 *u*m acetate filters at 130 mm Hg vacuum in the laboratory. Water samples will be frozen and shipped to the UC Davis Limnology Laboratory for analysis. Ammonium will be assayed with the indophenol method, nitrate-nitrite with the hydrazine method, organic nitrogen using kjeldahl nitrogen, and total phosphorous by persulfate digestion.

Determine chlorophyll *a* concentrations during every sampling period for the epilimnion and metalimnion and from the one percent light level. Store chl a samples at 4^{o}C in the field, then filter onto 0.45 *u*m cellulose acetate membrane filters with 130 mm Hg vacuum pressure. Place filters in centrifuge tubes and store frozen (-25^{o}C). Extract chlorophyll pigments in methanol for 12-24 hours then measure with a Turner model 10-AU fluorometer calibrated with a chlorophyll standard obtained from Sigma Chemical Company. Run samples before and after acidification to correct for phaeophytin.

Identify phytoplankton species composition and bio-volume once per month from June through October for the epilimnion and metalimnion and from the one percent light level.
Preserve phytoplankton samples in lugol's solution and ship to Eco-Logic Inc. Inverted fluorescent microscopy techniques will be used to determine phytoplankton species composition and biovolume.

Collect zooplankton every sample period. Pull vertical hauls with a 0.35 diameter, 1.58 m long, 80 um mesh conical net, with a removable bucket. Sample discrete depth intervals using a release mechanism. A General Oceanics flow meter modified with an anti-reverse bearing will be mounted in the mouth of the net to correct for net efficiency (clogging). Retrieve the net by hand at a rate of one meter per second from 10-0 m, 30-10 m, 60-30 m and 2 m above bottom to 60 m at the deep station in Redfish Lake. The shallow stations in Redfish and all stations in Pettit and Alturas Lakes will be sampled from 10-0 m, 30-10 m, bottom-30 m. Stanley Lake will be sampled from 10-0 m and bottom to 10 m. Samples will be preserved in 10% buffered sugar formalin. Techniques that will be used to subsample, count, and measure zooplankton were adopted from Utah State University (Steinhart et al. 1993) using techniques and length-weight relationships developed by McCauley (1984) and Koenings et al. (1987).

Liquid fertilizer (28-0-0 and 10-34-0) will be added weekly to Redfish, Pettit, and Alturas lakes from June through October 1999. The N: P ratios (20:1 by weight, 45:1 molar) are skewed toward very high nitrogen loads to prevent any possible occurrence of colonial N-fixing Cyanophyta. Approximately 217 kg of TP and 4,208 kg of TN will be added to Redfish Lake, 78 kg of TP and 1,540 kg of TN to Alturas Lake, and 35 kg of TP and 694 kg of TN will be added to Petitt Lake. Applications follow the natural hydrograph with different amounts added at different periods. Fertilizer will be applied by boat and will be directed by hose to the boat wake while traveling at 4-8 knots. A set number of parallel transects will be used for each lake, and boat speed is controlled by the amount of fertilizer applied for each particular date.

We will operate a smolt weir on the outlet of Pettit Lake and a screw trap on the outlet stream of Alturas Lake. This will enable us to estimate outmigration (overwinter survival) and PIT tag fish for survival estimates through the migration corridor. We are able to capture 100% of fish outmigrating from Pettit Lake. The screw trap on the outlet of Alturas Lake will capture approximately 25% of fish outmigrating from Alturas Lake (NMFS 1994). We will do a mark recapture study at four different intervals based on changes in discharge to estimate trap efficiency for different flow regimes. A detailed description of trap operations can be found in our Section 10 Permit #998 (NMFS 1996).

We will use horizontal and vertical gill nets to capture fish from Pettit and Alturas lakes to examine diet enabling us to determine predation/competition among the fish communities. After capture, fish will be measured and weighed, and then the stomachs removed and preserved in formalin for diet analysis. We will follow the procedures in Taki and Mikkelsen (1997) but anticipate curtailing our schedule to only sample four times a year.

g. Facilities and equipment

The office and laboratory for this project are located in Fort Hall, Idaho, approximately 220 miles from the Sawtooth Valley. In addition to our lab, we have the use of the Biolines laboratory that is located in the Sawtooth Valley. We utilize the Biolines lab for all limnological work and our lab for stomach analysis and otolith and scale readings. We also send nutrient samples to Cal State-Davis for processing, and phytoplankton and zooplankton samples are counted independently by the same individuals who have counted them since the inception of the project.

Our office is fully staffed and equipped to accomplish our work objectives for this project. Office equipment includes computers, facsimile machines, a copy machine, etc. We use a Hydroacoustics Technology, Inc. echosounder system for our hydroacoustic surveys. This project uses two boats for collecting samples and applying nutrients and two pick-ups for transportation to and from the Sawtooth Valley. We have two snowmobiles and a six wheel ATV, which are used to access the lakes and smolt sampling sites from late November through June. We use a screw trap and smolt collection weir on the outlets of Alturas and Pettit lakes, respectively.

h. Budget

The 13% increase in salary reflects two changes. When the proposal for this project was submitted last year it reflected the FY98 budget since the fiscal year for this project begins before BPA's fiscal year does. So for this proposal two years of cost of living increases were included, as well as the addition of a one month FTE biologist. The SBT's indirect rate is 28.43% of total salaries and fringe benefits.

Section 9. Key personnel

Doug Taki

Education: Idaho State University, B.S. in Biology with emphasis on fish ecology

Current Employer and Responsibilities:

Sockeye Research Program Manager July 1993 - present

SHOSHONE-BANNOCK TRIBES
FORT HALL, ID 83203

I am responsible for every aspect of the Shoshone-Bannock Tribes (SBT) Snake River sockeye research project and for ensuring that all contractual obligations are met. This includes writing annual Statement's of Work and an itemized budget, tracking expenditures, ensuring all tasks are completed, monitoring subcontractor performance, and completing Annual Reports to the Bonneville Power Administration.

I am the direct liaison between Tribal government and the IDFG, NMFS, BPA, IDEQ, and the USFS for all sockeye related management or research related issues. I represent the SBT on the Stanley Basin Technical Oversight Committee and share responsibility on the Fish Passage Advisory Committee and Anadromous Fish Managers forum.

I supervise one biologist, one full-time and one temporary technician, a limnology subcontractor, and coordinate field work with the IDFG whenever there is a need for help by either agency. In addition to supervising and working with everyone to assure all project goals are accomplished I conduct all hydroacoustic analyses and PIT tag evaluations.

StreamNet Steering Committee October 1996 - present

SHOSHONE-BANNOCK TRIBES
FORT HALL, ID 83203

My duties include evaluating proposed changes to our website, coordination of data transfers, integration of genetic data between researchers and StreamNet, and assisting others when needed.

Resident Fisheries Manager November 1991 - July 1993

SHOSHONE-BANNOCK TRIBES
FORT HALL, ID 83203

I was responsible for managing the fisheries resources on the 544,000 acre Fort Hall Indian Reservation.

Fisheries Field Biologist May 1990 - November 1991

SHOSHONE-BANNOCK TRIBES
FORT HALL, ID 83203

Expertise:

1) Techniques and methodologies for evaluating stream and riparian habitats, 2) Techniques and methodologies for evaluating lentic habitats, 3) experience with equipment necessary to sample fish (e.g. screw traps, weir operations, gill nets, electrofishers, etc.) and subsequent evaluations, 4) All phases of using PIT tags for evaluating migration performance of anadromous fish, 5) All phases of conducting and analyzing hydroacoustic surveys, 6) Sound background in statistics including a five day biometry workshop, 7) SCUBA certified

Publications:

six BPA annual reports
four BIA annual reports
two IDFG annual reports

Bert Lewis

Education: Utah State University, M.S. in watershed science
University of Colorado, B.S. in environmental, population and organism biology

Fisheries Biologist November 1998-present

Assist the Program Manager in administering sockeye salmon recovery actions in the SawtoothValley. Actions include: assessment of nursery lake productivity, trophic level interactions, and predator-prey interactions regarding *Oncorhynchus nerka* carrying capacities, evaluate other sockeye survival constraints and intra specific interactions, and evaluate different release strategies for captive brood reared fish.

Assist in technology transfer of sockeye information and activities between the Shoshone-Bannock Tribes and other entities involved in sockeye research and management.

Assist in coordinating, communicating, and transferring project information to the general Tribal membership, fish and wildlife agencies, other Indian Tribes, and the general public.

Research Biologist May – November 1998

Utah State University
Logan, Utah

Worked on National Science Foundation project examining aquatic ecology and food web dynamics using stable isotope tracers (N^{15}) in oligotrophic lakes. Responsible for sample collection and processing, data management, and statistical analysis.

Section 10. Information/technology transfer

Current results are provided at semi-monthly TOC meetings. The minutes from TOC meetings are public and may be obtained from the BPA. Project activities and results are provided in an annual report to the BPA.

Congratulations!